

## NOTES

IMPACT OF A NON-NATIVE PLANT ON SEED DISPERSAL OF A NATIVE.—*Salsola tragus* L. (Mosyakin 1996), or tumbleweed, was introduced to the United States from Eurasia in the late 1800's (Young 1991). It has subsequently invaded large portions of the arid western United States and Canada. The impact that *Salsola* spp. have upon neighboring native plant survival during succession has been the subject of a number of studies (e.g., Lodhi 1979; Allen and Allen 1988; Johnson 1998). However, the impact of the invader upon the seed dispersal of natives has not been quantified. Plants such as *Salsola* spp. that have a shrubby growth form act as barriers that slow wind currents and trap wind-dispersed seeds (Day and Wright 1989). *Salsola tragus* often reaches densities higher than native species on disturbed sites. As a result, *S. tragus* may impact the seed dispersal of other species to a greater extent than natives with a similar architecture. Thus, the presence of the non-native *S. tragus* has the potential to alter the ability of natives to colonize successfully by altering seed dispersion patterns and plant survival.

Castle Mountain Mine near Searchlight, NV, contains a large (ca. 50 ha) overburden area where unusable excavated material from deep within the mountain is piled. The surface consists of heavily compacted rock fragments with nutrient-poor (total Kjeldahl nitrogen <1.5 mg/g, alkaline (pH = 8.0) soils that have little organic matter (<1.59%) and clay (<1.0%) (Walker unpublished data). The most common colonizers include the non-native annual *S. tragus* and the more diffusely constructed native annual *Eriogonum deflexum* Torrey (Hickman 1993), or flat-topped buckwheat. Although both species have wind-dispersed seeds, the two plants differ in their specific mechanisms of seed dispersal. *Salsola tragus* disperses its seeds after the main stem abscises at the base. The wind subsequently pushes the elliptical plants, jarring seeds loose from leaf axils as the plants bounce on the ground over a considerable distance. Stallings et al. (1995) found that *Salsola tragus* seeds were evenly distributed across the landscape if they were dropped during the tumbling phase. Seeds were concentrat-

ed in areas below the plant before the stem abscised and where the plant came to rest for a time (i.e., obstructions). By contrast, *E. deflexum* have winged seeds carried from the maternal plant by wind currents. The dispersal of these seeds depends upon the speed and direction of the wind, which may be altered by plants in the area. *Salsola tragus* in southwestern Wyoming had wind speeds of 13 m/sec one meter above the plant, 11 m/sec 15 cm above the plant, 9 m/sec 10 cm in front (i.e., upwind) of the plant, and 2.5 m/sec 10 cm behind (i.e., downwind from) the plant (Allen & Allen 1988). We hypothesized that *S. tragus* plants provide a barrier to *E. deflexum* seed dispersal through slowed wind currents. *Eriogonum deflexum* plants may in turn affect *S. tragus* seed dispersal by furnishing a physical obstruction to movement during the tumbling phase.

On the overburden pile at Castle Mountain Mine, we selected a flat, 600 m<sup>2</sup> plot dominated by *S. tragus* and, to a lesser extent, *E. deflexum*. We haphazardly chose sixty plants representative of the entire 600 m<sup>2</sup> plot: fifteen each of live *S. tragus*, dead (but attached to the ground by the main stem) *S. tragus*, live *E. deflexum*, and dead *E. deflexum*. Most plants chosen were at least 50 cm from their nearest neighbor (dead *E. deflexum* were occasionally as close as 20 cm to their nearest neighbor). In September 1996 we collected seed and plant litter within a 10 cm × 15 cm quadrat under each plant and from the nearest plant-free clearing within 25 cm to 100 cm east of each focal plant's eastern canopy edge. We used the difference between each canopy sample and its adjacent open area for analysis. This approach adjusted for differences in species substrate preferences on a microsite scale (e.g., living *E. deflexum* were more common in seed-catching rocky areas while living *S. tragus* were more common on sandy substrates). Litter was separated from the inorganic soil by sieving each sample and floating the organic matter. Each litter sample was dried and weighed. Due to the time-consuming nature of seed counting, five random samples from each treatment were selected for seed counts. All seeds were identified for each sample,

TABLE 1. DESCRIPTIVE STATISTICS FOR ALL STATUS AND SPECIES COMBINATIONS ADJUSTED FOR MICROSITE (UNDER CANOPY—ADJACENT OPEN AREA) [MEAN (SE)]. Seed densities expressed as number of seeds per cm<sup>2</sup>. Litter mass expressed as grams dry weight per cm<sup>2</sup>.

	Dead <i>E. deflexum</i>	Live <i>E. deflexum</i>	Dead <i>S. tragus</i>	Live <i>S. tragus</i>
Seed densities				
<i>E. deflexum</i>	1.35 (1.20)	4.30 (1.93)	9.62 (4.31)	2.32 (1.24)
<i>S. tragus</i>	0.23 (0.19)	0.09 (0.09)	4.05 (2.78)	3.85 (1.30)
Litter mass	0.0010 (0.0005)	0.0139 (0.0024)	0.6720 (0.2390)	0.0315 (0.0053)

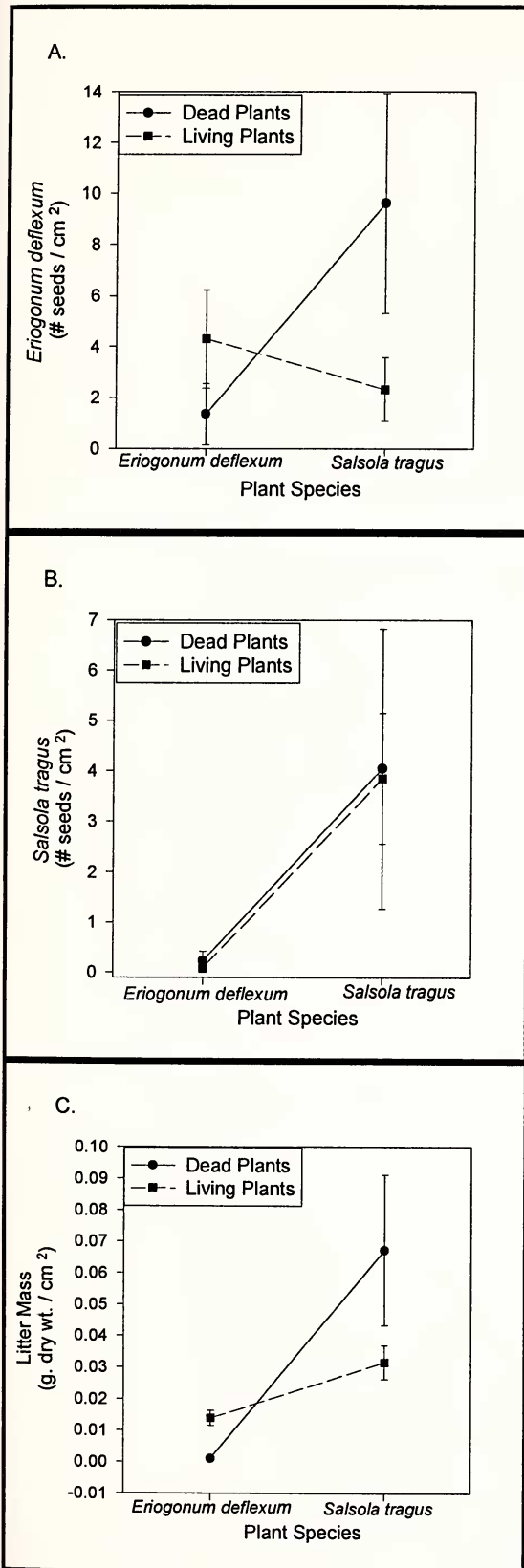


TABLE 2. SUMMARY FROM TWO-WAY ANOVA WITH STATUS OF PLANT (DEAD OR ALIVE) AND SPECIES (*E. DEFLEXUM* OR *S. TRAGUS*). Seed densities and litter adjusted for microsite (under plant—adjoining open area) and natural log transformed prior to analysis. F ratios are reported, with asterisks denoting significance level (\* =  $P < 0.050$ ; \*\* =  $P < 0.010$ ).

Source of variation	df	<i>E.</i>		df	Litter
		<i>deflexum</i> seed density	<i>S. tragus</i> seed density		
Status	1	0.01	0.14	1	16.19**
Species	1	0.00	10.77**	1	50.95**
Status × Species	1	0.40	2.61	1	18.81**
Error	16			56	
Total	19			59	

but seeds other than *S. tragus* and *E. deflexum* were very rare and not included in the analysis. The data were analyzed with a two-way ANOVA (Minitab 1991) which included main effects of species and status (dead or alive) and the interaction between them.

## RESULTS

Samples from open areas had less litter (mean  $\pm$  SE;  $0.003 \pm 0.001$  vs.  $0.032 \pm 0.007$  g. dry wt./cm<sup>2</sup>), fewer *E. deflexum* seeds ( $1.30 \pm 0.54$  vs.  $5.69 \pm 1.39$  seeds/cm<sup>2</sup>), and fewer *S. tragus* seeds ( $0.19 \pm 0.08$  vs.  $2.25 \pm 0.84$  seeds/cm<sup>2</sup>) than areas under plant canopies, as expected. After adjusting the under plant sample for microtopography using the open sample, the presence of *S. tragus* plants resulted in *E. deflexum* seed densities statistically equal to those under living *E. deflexum* plants, regardless of plant status (Tables 1 and 2; Fig. 1A). These results suggest that *S. tragus* plants served as an effective trap for *E. deflexum* seeds. However, *S. tragus* seed density was more than 16 fold greater under *S. tragus* than under *E. deflexum* (Tables 1 and 2; Fig. 1B), indicating that the native *E. deflexum* does not provide a major barrier to tumbling *S. tragus*. Plant status, species, and the interaction between them were all significant for litter data (Tables 1 and 2; Fig. 1C). Thus *S. tragus* plants were also more effective than *E. deflexum* in catching and/or retaining litter under the canopy.

The data suggest that *E. deflexum* seeds under *E. deflexum* fall from the plant and are blown away, while *E. deflexum* seeds under *S. tragus* have been captured by the slowed wind currents (Fig. 1A) and

FIG. 1. Interactions between plant status and species for a) *Eriogonum deflexum* seeds, b) *Salsola tragus* seeds, and c) litter [mean  $\pm$  SE]. Means adjusted for microsite by subtracting adjacent open sample from canopy sample. Numbers shown in Table 1.

perhaps held by litter under dead *S. tragus* (Fig. 1C). Figure 1B indicates *S. tragus* seeds under *S. tragus* plants probably came from the plant above them, since *E. deflexum* had very few *S. tragus* seeds under their canopies (Table 1). We conclude that *S. tragus* has a significant effect upon the dispersion of *E. deflexum* seeds, but *E. deflexum* plants do not affect the dispersion of *S. tragus* seeds. However, the time period for which this pattern is obtainable may be strongly influenced by tumbleweed abscission later in the season, a possibility not addressed in this data set.

Further work is needed to identify the overall impact that the seed-catching function of the alien *S. tragus* has upon native seedling establishment and plant success. We showed that a native plant's seed distribution can be affected by *Salsola tragus*. Other work has indicated that *Salsola* spp. can positively or negatively interact with nearby natives throughout the plants' lives. Allen and Allen (1988) propose *Salsola kali* may facilitate native grass seed colonization and establishment but may later com-

pete with adults for water and nutrients. *Salsola kali* has an extensive root system and efficient uptake of phosphorus (Itoh and Barber 1983). In addition, *S. kali* can significantly alter soil nutrient concentrations in mixed culture, perhaps due to its rapid growth rate (Allen 1982). *Salsola tragus* can even make phosphorus more available to neighboring plants through a high oxalate concentration in canopy leachates (Cannon et al. 1995; Hageman et al. 1988). Clearly, *Salsola* spp. affect neighboring natives, but the net effect of this interference is unknown. This study has shown that *Salsola* spp. can concentrate native plant seeds under the *Salsola* spp. canopies, where germination and growth may then be either facilitated or inhibited. Further understanding of the effects of *Salsola* spp. on native colonizers will enhance efforts to reintroduce native species to damaged ecosystems.

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